2006-2046: THINKING AND DOING MATH AND SCIENCE WITH ENGINEERING: A PARTNERSHIP

Jerry Hamann, University of Wyoming

Jerry Hamann is an Associate Professor of Electrical and Computer Engineering in the College of Engineering at the University of Wyoming. He is also currently serving as the director of the University of Wyoming Hewlett Foundation Engineering Schools of the West Initiative.

Linda Hutchison, Bristol Community College

Linda Hutchison is Associate Professor and Head of Secondary Education in the College of Education at the University of Wyoming. Her interests include math education across K-12.

Alan Moore, University of Wyoming

Alan Moore is an Associate Professor of Educational Leadership in the College of Education at the University of Wyoming.

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Introduction

During the summers of 2004 and 2005, the Colleges of Engineering and Education at the University of Wyoming teamed up to provide engineering topics-based workshops for K-12 teachers. The workshop topics focused upon contemporary engineering technology and applications, providing a foundation for inquiry-based lessons in K-12 math and science classrooms.

In this paper, the authors summarize the motivation and mechanics behind the first two years of workshops, involving over 40 teachers and a cadre of University of Wyoming faculty, graduate and undergraduate students. While taking part in the workshops, the K-12 teachers were responsible for constructing lesson plan modules targeted at standards-based delivery of math and science with engineering topics as the underlying base for investigation. Summaries of the variety of modules generated, both in grade level and content, are provided, along with feedback from participants who have put the modules to work in their classrooms.

The efforts described here are motivated by several factors: Shrinking regional enrollment projections for undergraduate science/math and engineering programs, the need to assist teachers with investigative topics in math and science which align efficiently with state education standards, the desire to present students with the context of engineering practice throughout the K-12 program of study, as well as the hope to solidify communication channels between collegiate and K-12 education partners. The efforts have been enabled by funding from the Department of Education as well as the Hewlett Foundation and will continue with a workshop during the summer of 2006.

The Motivation

The future of U.S. technological competitiveness is a function of the degree to which able students (including women, ethnic minorities, and persons with disabilities) will pursue careers in engineering and science. The best opportunities for employment and advancement will go to those prepared to deal confidently with quantitative, scientific, and technological issues. The U.S. Bureau of Labor Statistics has projected a 15.2% increase from 2000-2010 in the need for employees trained in engineering and other technical specialties[1]. However, the U.S. Department of Education's National Center for Educational Statistics has predicted a decrease in the number of high school graduates in Wyoming, and this decrease is also expected to occur in many of the Rocky Mountain and Midwestern states[2]. The declining number of college-age students, coupled with a declining interest in science and engineering careers, has serious implications for the U.S. economy and international competitiveness[3]. The picture is becoming quite clear; we must broaden and retain the pool of those pursuing technical careers[4].

One portion of the solution to meeting the projected workforce needs, in a climate exacerbated by declining high school populations, requires increasing the fraction of high school graduates pursing engineering careers. To increase the fraction, early exposure of K-12 students to the issues, applications, and opportunities in engineering is absolutely vital. In addition, we must pursue increased participation by traditionally underserved populations.

These motivating factors must be carefully weighed against the climate for instruction faced by K-12 teachers. Reflective of activities in most states, the Wyoming State Department of Education has adopted an aggressive schedule for implementing outcomes-based education standards as a requirement for high school graduation, covering the spectrum of student abilities as represented in the philosophy of the No Child Left Behind Act of 2001. All K-12 school districts in the state are currently integrating uniform topic material standards into existing coursework. Demonstrating compliance with Wyoming's standards while retaining local school control of programs has led to a significant level of confusion and anxiety for administrators, teachers, students and families.

Could this be a recipe for a match made in heaven (or at least, in the trenches of education across a largely rural, sparsely populated state)? National organizations with vested interests in this arena, including the National Academies, have promoted the development of education standards which prescribe technical content around which individual schools and teachers are encouraged to develop investigative, inquiry-based curricula[5]. In Wyoming, standards for mathematics and science have taken a form very similar to this. The link which is potentially missing is contemporary topic expertise.

The Partnership

Engineers, by practice, deal with technology at both the cutting edge and the well-refined. Advances in basic science find their niche in the technology of our day through the products, processes and facilities that engineers design and maintain. One might call us "the applied content experts," which is at least somewhat more complementary than "geeks." Science and mathematics are the faithful partners in our toolbox, as comfortable in our hands as a well worn wrench. We've both informally and formally entered the K-12 classroom over the years, perhaps by invitation on career day or as a precursor to the local science fair. Recently, we've even started to carve out very enticing fast-track-to-technical-career middle school and high school curricula in the form of efforts such as Project Lead the Way[6]. But we've yet to become a true partner in the mission our K-12 brethren undertake, including the demands of No Child Left Behind.

With these precursors in mind, the University of Wyoming Colleges of Engineering and Education have undertaken a multi-year project to bring K-12 teachers together with University content experts. The underlying objectives are succinct:

- Provide K-12 teachers with contemporary math and science application training through summer workshops.
- Assist K-12 teachers in developing inquiry-based lesson modules in math and science which satisfy content requirements of state standards for education.
- Support K-12 teachers through exchange of expertise and specialized equipment during the school year.

The formula is really quite simple: Engineers (scientists, mathematicians) provide teachers with a window into exciting, contemporary technology and support those teachers with their investigations, allowing the teachers to take this excitement and spirit of discovery back to their classroom in a form which will, hopefully (1) satisfy state standards for content, (2) introduce

students to the context of engineering, (3) possibly motivate more students to pursue technical fields of study.

The Search for Interested Stakeholders

Embarking on a grandiose plan to bring K-12 teachers and university-based engineers together as partners in education meets reality when the "how are we going to fund this" question is finally broached. As a sign of the times, both public and private entities have shown considerable interest in such efforts. In particular, the William and Flora Hewlett Foundation, through a novel and focused program presented as the Engineering Schools of the West Initiative[7], and the Wyoming Department of Education, through extension of the U.S. Department of Education Math and Science Partnership (Title II Part B)[8] Grants, have provided both the resources for this effort as well as an environment, with like-minded colleagues, in which to share ideas and wrestle with implementation assessment planning.

Structuring the Summer Workshops

Workshop topics have been refined to provide both a rich medium for technical inquiry as well as high potential for alignment with content standard, initially with emphasis upon mathematics. During each of the summers of 2004 and 2005, over a two-week resident program at the University of Wyoming, participants have been provided with four topic workshops, resulting in an immersion of approximately 12 hours per topic with guided hands-on investigation, and 6 hours of independent investigation for module development. The workshops have been presented by a combination of university faculty and graduate students, utilizing laboratories and resources within the Colleges of Engineering and Education. The workshop topic areas are summarized in Table 1.

Table 1. Summer Workshop Topics Presented in 2004 and 2005.

Workshop Title	Topic Description
Maps, Math and GPS	Principles of geodetic science, technologies including the Global Positioning System, maps and mapping through history and cultures.
Codes and Cryptography	Theory of coding and cryptography, historical context of use and implications of codes in warfare, commerce and communications.
LOGO Programming	Algorithmic geometric constructions, principles of programming languages and computation, visualization and modeling.
Electronics and Math	Fundamentals of electricity, theory of binary logic and computation, the hardware of electronic computation.

Topics for the summer of 2006 will expand to incorporate additional emphasis upon biological and physical sciences, as well as the engineering design process. Significant attention has been paid to strengthening collaborative ties between workshop participants and presenters through school-year sharing of expertise (visits to schools) and unique resources (the toys of technology).

The K-12 Participants and the Modules

The initial summer workshops have targeted, but not been limited to, teachers from Wyoming school districts which have reported significant need for assistance with achieving annual progress goals in math and science outcomes, as measured through standardized testing. Participants have been provided with room-and-board on the campus, access to recreational facilities, computer resources for collaboration (email, module construction and documentation), introductions to unique resources on the campus (technology laboratories and libraries), and promised a significant stipend following their development of at least two module lesson-plans, designed for their classroom and aligned with state standards for math and science. Table 2 summarizes the participants to date.

Table 2. Workshop K-12 Participant Summary

Workshop Year	Number of K-6 Teachers	Number of 7-12 Teachers	Diversity of Participants
2004	7	9	Kindergarten Language Arts, 3rd and 4th Grade, Middle School Science and Math, High School Math and Physical Sciences. Representing 7 separate school districts
2005	13	15	Elementary Librarian, Read/Writing/Math Resource Room, Special Education, 5th and 6th Grade, Middle School Earth and Biological Sciences and Math, High School Math and Physical Sciences. Representing 14 separate school districts

The on-line lesson planning facilities of TaskStream[9] have been utilized to archive and share the teacher-designed modules. Faculty from both the College of Education and Engineering have worked with the participants to enhance the inquiry-based format of the modules, encouraging changes in the classroom to draw upon the value of guided investigations for learning. Example module titles are provided in Table 3.

Table 3. Exemplar Modules Developed by Participants

Workshop Year	Grade Level	Module Title
2004	4th	**Binary Numbers**
2004	3rd and 4th	**Crack the Code**
2004	7th and 8th	**Where Does the Average Student Live?**
2004	11th-12th	**A Vector Walk**
2005	K-1st	**Mapping Our Classroom**
2005	K-6 Library	**Mapping in the Library**
2005	9th-10th	**LOGO Tesselations**
2005	11th	**Mining for Algebraic Gold**

The Nitty-Gritty Details of the Summer Workshops
Two full weeks in July have been utilized for the resident workshop on the campus of the University of Wyoming. An example schedule for the workshop is shown in Table 4, demonstrating the sequencing of topic immersion with coordination of group activities and free time for module development by the participants.

Table 4. Example Summer Workshop Schedule

Week One	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
8:30 – 11:30	*Travel Time*	TOPIC I: Maps, Math and GPS	TOPIC I: Maps, Math and GPS	TOPIC II: Electronics and Math	TOPIC II: Electronics and Math
Lunch					
1:00 – 4:00	*Registration and Intros, Pre-Surveys, Problem Solving Group Activities*	TOPIC I: Maps, Math and GPS	*Overview of Module Development, Available Resources, Intro to TaskStream*	TOPIC II: Electronics and Math	*Module Development Free Time*
Week Two	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
8:30 – 11:30	TOPIC III: Codes and Cryptography	TOPIC III: Codes and Cryptography	TOPIC IV: LOGO Programming	TOPIC IV: LOGO Programming	*Module Development Free Time*
Lunch					
1:00 – 4:00	TOPIC III: Codes and Cryptography	*Module Development Free Time*	TOPIC IV: LOGO Programming	*Post-Surveys, Planning for Academic Year Activities*	*Final Logistics, Travel Time*

Following this general scheme, 98% of modules have been completed to essentially final form by the end of the second week of the workshop. During the module development free time, as well as the unstructured evenings and weekends, teachers are provided with access to general computing resources for crafting lesson plans, designing handouts and guided worksheets, as well as the design of assessment rubrics. One-on-one interaction with the TOPIC experts, UW faculty and staff, is also enabled during these free times.

As the number of participants has grown over the past two years of this activity, two parallel cohorts of teachers (K-6 and 7-12, roughly) have followed a mirrored schedule (for example, the second cohort would pursue TOPICS III and IV during the first week, TOPICS I and II during the second week). Both groups are then brought back together at various points outside the TOPIC schedule for logistics discussions and to provide "cross-pollination" of ideas and interests. This structure has proven to be effective from the perspective of both the teachers as well as the TOPIC experts.

Feedback from the Participants

The K-12 teachers were asked to respond to surveys presented at the beginning and then the completion of the summer workshops as well as, in the case of the 2004 cohort, at the end of the subsequent school year. Most of the participants shared that the workshops were very informative, ideas and concepts were presented in a fun way with applications to the classroom. The workshops helped them to learn, review and develop new math concepts.

A notable difference was found between elementary (K-6) and secondary (7-12) participants when questioned regarding their comfort with technology use in inquiry-based learning, indicating that additional assistance can be helpful in bolstering the K-6 audience confidence with technology in the classroom. Successful incorporation of modules in the classroom will likely depend upon this training and support. A promising sign should be noted with regard to the near unanimous appreciation for the on-line lesson-planning facilities provided by TaskStream.

The majority of participants expressed significant interest in bringing the content (TOPIC) expert collaborators into the classroom. Indeed, when asked in the "pre" and "post" workshop surveys regarding their comfort level with various aspects of the program, the most significant increase in comfort level was expressed for "contacting and collaborating with the workshop presenters and facilitators." And indeed, these collaborations have continued well into the school year.

Conclusion

The K-12/University partnership underlying this project reflects what the authors see as a vital step, integrating a distributed expertise in content specialty, educational design, and in-the-trenches instruction. We see this linkage as one which holds the potential for encouraging more young people to pursue, if not careers and further study in technical fields, at least a genuine appreciation for and understanding of the essential role technology plays in our contemporary culture. We hope that by building bridges such as these, the vision for newer designs will bridge gaps well into the future.

Bibliography

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